



Search for O VI Emission from the Shocked Circumstellar Ring of SN1987A

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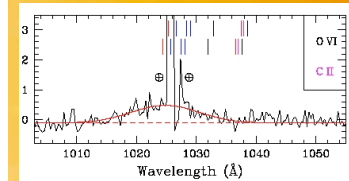
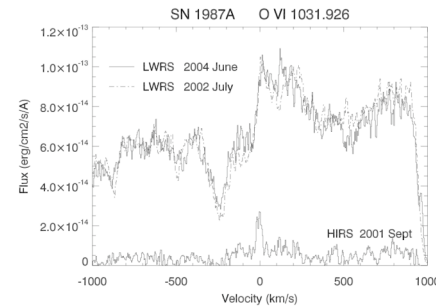


Abstract

We used the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite to search for broad O VI 1032-38 Å emission from the shock interaction zones produced by the collision of high-velocity SN1987A ejecta with the dense inner circumstellar ring. Since the shock interaction with the inner ring began in the mid-1990s, broad (FWHM ~ 300 km/s) emission from optical coronal lines (e.g. [Fe X], [Fe XI], and [Fe XIV]) has emerged and increased exponentially in strength. O VI 1032-1038 emission is expected to track the coronal lines. O VI is also expected to be the primary cooling transition for the million-degree shocked gas. As of November 2004, no broad O VI feature has been detected. An upper limit on the intrinsic O VI flux is $\sim 1.E-13$ erg/cm²/s (corrected for foreground MW and LMC extinction).

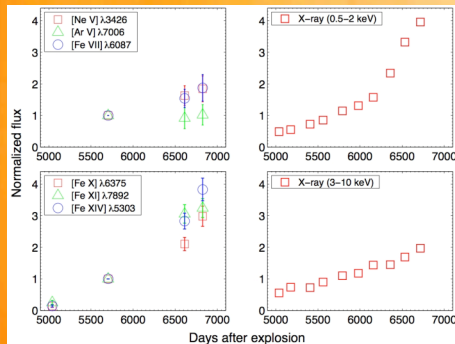
An accurate measurement of the O VI line strength would significantly improve current models of the shock interaction. FUSE observations in 2000 and 2001 to detect broad O VI from SN 1987A were inconclusive due to spectral contamination from two early-type stars within a few arc seconds of the SN. We did detect VI emission with narrow line profiles with FWHM <35 km/sec, and a heliocentric radial velocity of +280 km/sec. This places the emitting gas at rest relative to the supernova.

A new FUSE observation in 2007 or early 2008 will use a narrow slit (1.25x20 arcsec) to significantly reduce the effect spectral contamination from the two early-type companion stars.

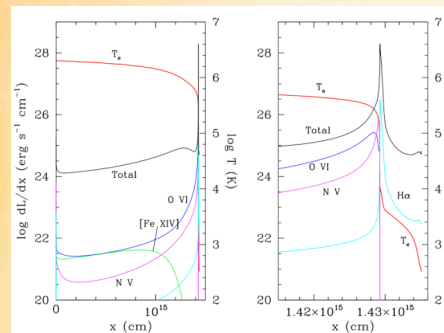


A FUSE spectrum of the LMC supernova remnant SNR 0509-675, showing a broad component on the Lyβ line. The vertical scale is in units of 10^{-14} ergs cm⁻² s⁻¹ Å⁻¹, demonstrating how very faint, broad emission lines are detectable with FUSE. This spectrum represents 9.7 ks of orbital night data extracted from a longer (~25 ks) total exposure. Tick marks show the positions of potential narrow Milky Way and (redshifted) LMC ISM absorptions, not all of which are actually present. (from Ghavamian et al. 2006)

LEFT - The O VI 1032 region (at $v_{\text{helio}} = +280$ km/s) in three FUSE observations. All spectra have been processed with CalFUSE3. Narrow O VI is obvious in the HIRS spectrum. There is a slight flux excess in the LWRS 2004 spectrum within ± 250 km/s of line center that might be due to shocked O VI emission. This gives an upper limit on O VI of 8×10^{-15} erg cm⁻² s⁻¹ (observed flux).

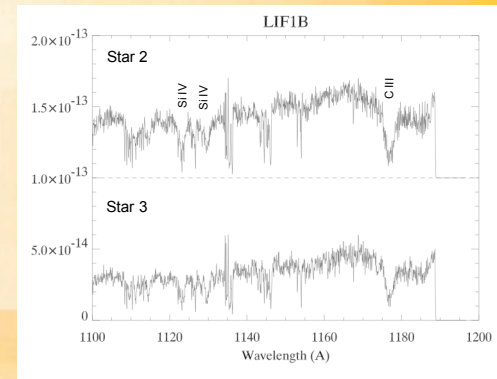


Light curves for optical high-ionization lines (left panels) and for soft and hard X-rays (right panels) from 1995 through 2005 (figure from Groningsson et al. A&A 456,581, 2006)



Groningsson (2006) have modeled the shock interaction taking place in the inner ring and find good agreement with the observed optical coronal lines. Figure 2a shows the cooling rate per unit distance (left-hand axis) and temperature (right-hand axis) behind a radiative shock with velocity 350 km/s and pre-shock density 10^4 cm⁻³ for several transitions: O VI, N V, Hα, and [Fe XIV]. The left-hand panel shows the total shock, while the right-hand panel shows the cooling region in more detail. The cooling occurs in a very thin region where the temperature drops from $\sim 10^6$ K to $\sim 10^4$ K. Note the importance of the O VI line, probing the cooling region, while the [Fe XIV] line mainly probes the immediate post-shock region and the H-alpha line the cool, photoionized region. The region of maximum cooling behind the shock is currently unconstrained by the available data. Measurement of O VI from this shock region will solve this deficiency and improve predictions for future shock development.

O VI is predicted to track the exponential growth of the coronal lines and soft X-rays. The [Fe XIV] light curve indicates that O VI should increase significantly, at least a factor of 3-5X, between the most recent FUSE observation of SN1987A (2004 June, day ~6300) and the next observation in 2007 or 2008 (day 7500-7800). The shock models predict O VI to be the strongest UV emission line by an order of magnitude, and ~100X the strength of the optical Fe coronal lines.



FUSE spectra of Stars 2 and 3 obtained in 2001. The spectral resolution is ~20 km/s. Several stellar features are labeled. Interstellar lines have Milky Way and LMC absorption components, separated by about 1 Å.